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Hamilton County, Indiana

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Fossil Pollen Analysis of Fox Prairie Bog, Hamilton County, Indiana¹

By ROBERT L. PRETTYMAN

The study of post-Pleistocene vegetations and migration of forests by means of fossil pollen in peat is a comparatively recent addition to the study of paleobotany and plant geography in America and is certainly in its pioneer stage in Indiana; yet that state offers a rich field to the botanist interested in the postglacial migration of vegetation. In the northern part of the state, numerous bogs in various stages of development, ranging from the open lake stage to those completely covered by sedge or forest, are readily accessible for study. In central Indiana, bogs are less numerous, but all the more interesting, because they mark the southernmost extension of glacial bogs in Indiana.

Indiana occupies a unique position in the glaciated section of the United States. It marks the southern terminus of both the older Illinoian and the more recent Wisconsin ice sheets. The former extended all the way to the southern boundary of the state, with an unglaciated triangle (Malott, 8) from northern Monroe and Brown counties at its northern apex to Posey and Clark counties in the south. The Wisconsin glacier reached its southern terminus at a line crossing from the northwest corner of Jennings county to central western Parke county.

The glacial bogs in Indiana are all in the Wisconsin deposits. While surface records of boreal plant relics are almost obliterated by the activities of civilized man, i. e., fires, draining and grazing, the records of the great migrations of forest types and climaxes are still neatly stored away unmolested in the peat of our deep bogs, open to the inspection of the botanist who is ready and willing to spend physical labor to collect peat and who has the patience necessary for microscopic analysis.

During the past year the Butler University Botanical Laboratory has undertaken an extensive and intensive study of Indiana bogs; records of surface vegetation are being gathered, and other pertinent data are being collected from the oldest settlers of the region in question, which in most cases covers a period of seventy-five years. One of the deeper bogs in the group studied at present is the Fox Prairie bog, in Hamilton county, Indiana. Data on this bog are here reported.

¹This paper is a portion of a thesis in partial fulfillment of the requirements for the degree of Master of Arts in Butler University.

GEOGRAPHICAL LOCATION AND DESCRIPTION

The Fox Prairie bog is located three miles north of Noblesville in Hamilton county, which is situated slightly north of the geographic center of Indiana. The bog is located in an old valley or glacial channel on the west side of the West Fork of White river (6). This surrounding country varies from a level till plain to an undulating and somewhat hilly topography. The area is characterized by a beech-maple climax with an oak-hickory subclimax on the drier uplands.

PLANT ASSOCIATIONS

The bog covers approximately three-fourths of a square mile. Those areas which are not too wet are under cultivation and the black soil reveals its organic origin. The old lake shore is marked by encircling sandy ridges. The central and larger portion of the bog is occupied by an extensive Calamagrostis meadow. *Populus tremuloides* is by far the most abundant tree and is found in patches and small groves. The trees are all young, probably none exceeding fifteen years in age. *Acer rubrum* and *A. saccharinum* are represented by scattered trees. *Salix nigra* is common in the more moist locations, along the drainage ditches and around the margins of the open water. *Ilex verticillata* is the most abundant shrub. *Rhus vernix* is also present though not in great abundance. *Osmunda cinnamomea*, *O. regalis spectabilis*, *Dryopteris thelypteris pubescens*, and *D. cristatum* are the most prominent ferns. The absence of any significant boreal relicts may be due to the age of the bog, together with the destruction by fires and pasturing.

METHODS

In the winter of 1936-37, two borings were made approximately 400 feet apart near the center of the bog, and samples taken at one-foot intervals. These borings, hereafter referred to as Spectra A and B, were 40 and 41 feet deep respectively. The boring was done with a borer of the cylindrical type, having a movable sleeve. The cylinder was thoroughly washed between samples to avoid contamination. The samples were always taken from the center of the core and placed into a clean vial, corked and labelled. The lower 11 feet in each boring were composed of a bluish-gray marl, indicating that an open lake stage had existed over a rather extensive period. In both borings the marl was

nderlain by a coarse, hard-packed sand which the boring apparatus could not penetrate.

The fact that the bog was 41 feet deep was rather striking, as the surrounding terrain would not suggest the existence of so deep a lake. Leland (2) states that such lakes and ponds, the so-called kettle holes, probably have as their origin huge blocks of ice which had been buried in the glacial drift and melted to form rather deep but not extensive bodies of water.

The procedure followed for the preparation of the peat for microscopical analysis approximated that used by Geisler (4). This method worked quite satisfactorily, yielding a large number of grains per slide at levels where pollen was abundant. Basic fuchsin (1 per cent aqueous) was used to stain the grains in the marl. This stain worked much better than either methylene blue or gentian violet. In the peat, aqueous gentian violet (1 per cent) gave excellent results. It was found that when used to stain the pollen grains in the marl, gentian violet gave little or no results. This was probably due to the alkaline nature of the marl, since the grains in slightly acid peat took the stain readily. The amount of peat to be used in the preparation of slides for a given level depended largely upon the abundance of pollen. This was determined by a preliminary examination of the mounts. If this examination revealed the pollen to be abundant, a lump of peat about the size of the thumbnail was separated in about 15 cc. of alcohol. If the frequency was low, a still larger lump was used. The amount of gentian violet used for staining was inversely proportionate to the degree of acidity of the peat. Grains in peat approaching neutrality were found to require more stain than those in the upper or more acid levels.

PEAT ACIDITY

The hydrogen-ion concentration of samples taken from Spectrum A was determined by the Youden hydrogen-ion concentration apparatus. Three readings were made of each sample. The active acidities of these were averaged, and from this the pH values were obtained. The peat was most acid (pH 5.7) near the surface, with a steady decrease in acidity as depth increased. At the 29-foot level, or in the first foot of marl, the reaction was neutral, and from here to the 41-foot level there is an increasing alkalinity.

EXAMINATION AND IDENTIFICATION

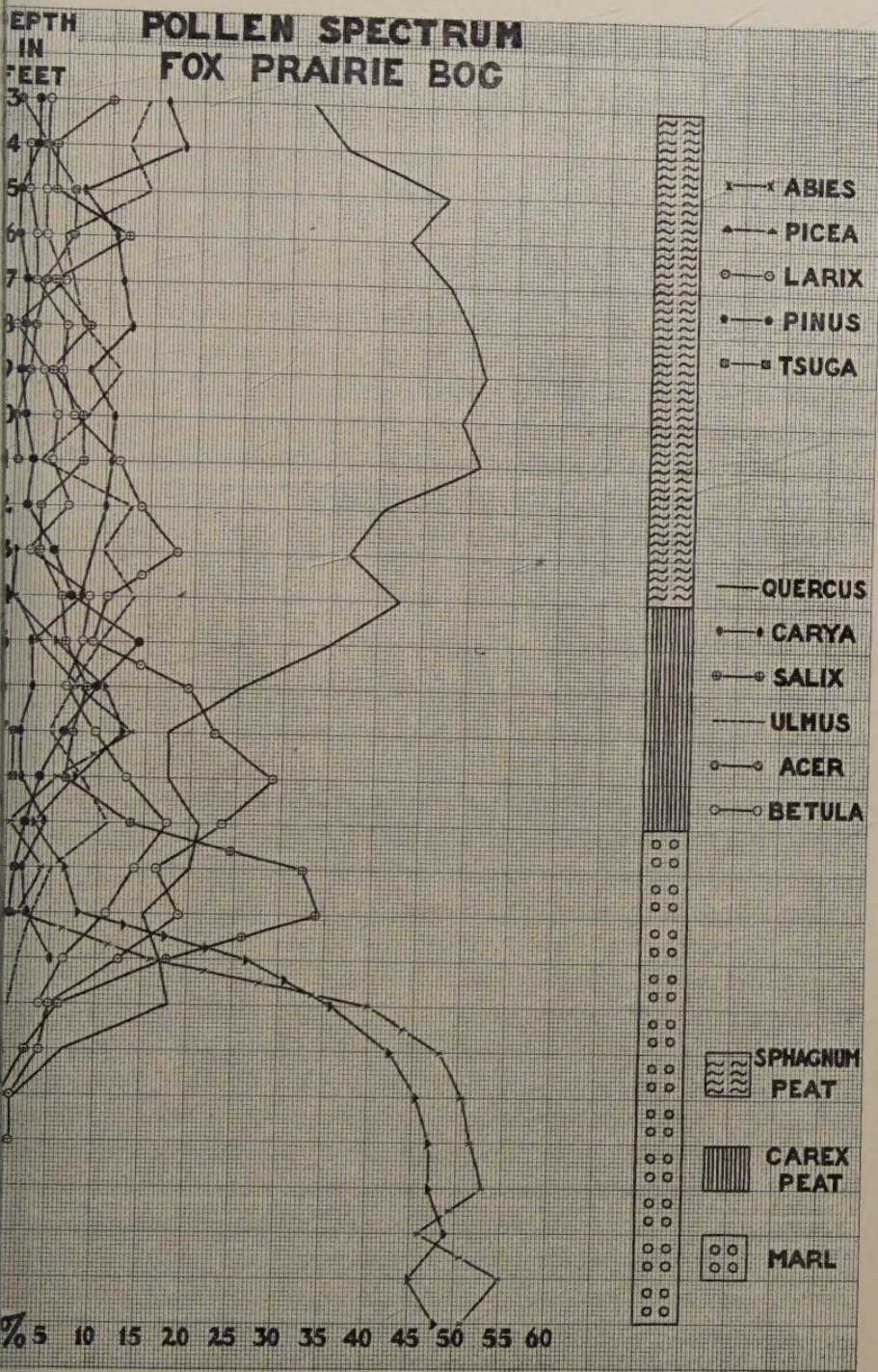
A binocular microscope equipped with 15X oculars, 43X objective, graduated mechanical stage and condenser, was used for identification and examination of the pollen. The grains were identified by comparing them with prepared slides of modern pollens. The works of Wodehouse (16), Sears (12) and Lewis and Cocke (7) were also helpful in identification. Examination of the upper 12 feet of peat in both borings revealed a marked absence of pollen. For the most part, 200 grains were counted in each level, with the exception of those in which the pollen frequency was so low as to prohibit it. This was true of the 13-, 14-, 15- and 16-foot levels of Spectrum A, and the 38-, 39-, 40- and 41-foot levels of Spectrum B. In all instances the unknown grains were included in the total number of grains counted for each level.

OBSERVATIONS

The results of the microscopic analysis of Spectrum A are presented in Figure 1. Those of Spectrum B are not here shown, but will be supplied to anyone wishing them by the Botany Department of Butler University. The percentages were derived from the total number of grains counted for each level. In general, the two spectra are similar. The lower levels are characterized by high percentages of *Abies* and *Picea* grains and the total absence of any other genera. This is followed by increasing percentages of *Larix* and *Pinus* pollen, with a decrease in *Abies* and *Picea*. Grains of *Larix* and *Pinus* extend well into the upper levels, but only in small percentages. Such genera as *Juglans*, *Corylus*, *Betula* and *Alnus* tend to appear early in the lower levels, but in no great abundance throughout the spectra. The grains of *Quercus*, *Salix*, *Carya* and *Ulmus* comprise the bulk of the pollen of the broad-leaved forms. In several levels, *Quercus* comprises over 50 per cent of the total number of grains counted. The grains of the unknown genera tend to increase toward the upper levels. The most striking difference between the two spectra is in the percentages of *Abies* and *Picea* in the lower levels. In Spectrum A these two genera are rather equally divided, while in Spectrum B *Abies* reaches a maximum of 86 per cent.

Figure 1 shows graphically the percentages of the more important genera found in Spectrum A. *Abies* and *Picea* exhibit a rather gradual decline up to the 31-foot level, in which both species almost disappear. This is followed by a small increase, finally to disappear in the 23- and

FIGURE 1



24-foot levels. *Larix* reaches a striking maximum in the 28-foot level. In general, most of the broad-leaved genera are characterized by a steady increase after making their appearance. However, in the 27- and 38-foot levels all these genera are subject to a definite and, in some instances, an abrupt decrease. *Quercus* is the most outstanding of the broad-leaved genera, attaining a maximum of over 50 per cent in the 18-foot level.

DISCUSSION

One of the most striking features of the bog was the absence of pollen in the upper levels of the peat. Analysis revealed the pollen frequency so low that counting was prohibited. Fern spores and sporangia were abundant throughout these levels and gave evidence of a rather densely covered bog mat having its vegetation above the water level. Davis (3) believes that this dead vegetation when exposed to the air and sun created a poor medium for the preservation of the pollen. A bog similar to Fox Prairie bog, in that the upper 12 feet had pollen frequencies too low to permit counting, is recorded by Voss (14) for the Bald Eagle bog of northern Minnesota.

THE SUCCESSION OF FOREST TYPES

The forest types and their succession are best seen in Spectrum A, Figure 1. The high percentages of *Abies* and *Picea* in the lower levels indicate a coniferous forest dominated by these two genera. No broad-leaf nor unknown species were recorded from the lower levels of marl, indicating that this forest was for a period relatively stable. *Abies* and *Picea* disappear gradually and are replaced by *Pinus*, *Larix* and several broad-leaved genera, such as *Salix*, *Quercus*, *Ulmus*, *Betula*, *Corylus*, *Carya* and *Alnus*. *Pinus* and *Larix* finally give way to the broad-leaved forest, which in the upper levels appears to be essentially oak-hickory. As to what the upper twelve feet might have shown had the pollen been preserved, one can only infer from other records. Jean P. Barnett, a fellow investigator at the Butler University Botany Department, working on a bog near Emporia, Madison county, found a strong tendency toward a beech-maple climax in the upper eight feet of the Emporia bog. This seems to be true in the Fox Prairie bog, too, as indicated by the decline of *Quercus* and the appearance of *Acer* in the 15-, 14- and 13-foot levels. On the other hand, one must consider the question of whether or not the pollen grains which fell into the bog at this period were characteristic of large areas of the surrounding forest. The regions adjacent

to the bog were an old sandy shore line and an area of wet lowlands. The former probably supported primarily oak-hickory and the latter was no doubt dominated by an elm-walnut subclimax forest, while the bog itself was probably covered by a *Thuja*-*Larix* relic vegetation, as were most of the remaining bogs in Indiana when civilized man moved in. This, of course, is only conjecture. One must, however, always bear in mind that the deciduous forest is heterogeneous and forest types are determined by local environmental conditions, and depositions in a bog are under control of this limited local environment.

THE FOREST TYPES AND THEIR SIGNIFICANCE AS CLIMATIC INDICATORS

The forest type which a given area will support is determined by climatic, edaphic and topographic factors. If these factors undergo change, the existing forest type will be replaced by one better fitted to meet the conditions of the changed environment. With the retreat of the Wisconsin glacier, there was initiated a change in the factors which control forest types. Conifers, such as *Abies*, *Picea*, *Pinus* and *Larix*, which had been pushed southward by the advance of the ice, were among the first trees to advance over the barren drifts left by the glacier. As the huge ice masses retreated farther northward, the climate in a given region changed and the conifers were forced farther northward by climatic factors and by new forest types crowding in from the south.

The climate which existed during the dominance of *Abies* and *Picea* in the Fox Prairie area was apparently the same as that of the region in which the northern conifers are now found, i. e., the so-called boreal forest. The northern boundary of this area runs from the Mackenzie delta to the east of Great Bear and Great Slave lakes to Fort Churchill in Hudson bay; it then swings around the bay to the northeast, but reaches the coast only near Newfoundland. From Cook inlet in Alaska the southern boundary trends southeastward to Saskatchewan, eastward to Lake Winnipeg and thence to northern New Brunswick (15).

No sudden change from one forest type to another was revealed in the spectrum. The change from coniferous to broad-leaved forest (36- to 22-foot levels) was a very gradual one in which *Larix* and *Pinus* reach their maxima and slowly decrease. The earlier part of this transitional period is characterized by the appearance of genera comprising the broad-leaved forest and especially the rather rapid increase of *Quercus* (36- to 29-foot levels). This would seem to indicate a somewhat drier

and warmer climate than when the conifers were dominant. This is followed by a rather sudden decrease in the broad-leaved forest, which is revealed in all the genera (28- to 27-foot levels). At this time, *Abies* and *Picea*, which had almost disappeared (29-foot level), make a notable increase, and *Larix* reaches its maximum (28-foot level). This points toward a return to the cooler and more moist climate which existed earlier.

The later part of the transitional period marks the disappearance of *Abies* and *Picea* (24- and 23-foot levels) and the increase of *Quercus*. The other broad-leaved genera tend to increase generally and *Pinus* reaches its maximum (25-foot level). This would suggest the tendency toward a drier and warmer climate than existed previously, probably similar to that of the present Lake Forest area (15).

The broad-leaved forest had by this time become well established, and *Pinus* and *Larix* apparently existed only as relict (20- to 16-foot levels). The forest type was essentially oak-hickory and was controlled by a climate somewhat similar but perhaps less moist than that of today. This period of a drier climate may be in some way correlated with the eastward extension of the prairie, which is known to have extended farther eastward in earlier times than it does today (13).

The upper levels (15- to 13-foot levels) give evidence of a return to a more moist climate. *Quercus* decreases rapidly and *Acer* makes its first appearance. Analysis of the upper 12 feet, had it been possible, would probably have recorded the change from a rather dry, warm climate, supporting oak-hickory, to a moist, warm climate, supporting beech-maple, which exists in the area today.

COMPARISON OF RESULTS AND INTERPRETATIONS WITH THOSE OF OTHER WORKERS

The evidence of a coniferous forest dominated by *Abies* and *Picea* in the lower levels of the Fox Prairie bog is typical for the majority of the bogs in Wisconsin, Illinois, Minnesota, Michigan, Ohio and Indiana, that have been investigated by Voss (14), Sears (10), Houdek (5), Artist (1) and Lindsey (9). Sears (11) found evidence to suggest that five or six climatic cycles have occurred in postglacial times. This is in contrast with the findings of Voss (14), whose studies reveal the climate to have been uniform. The present work tends to support the opinion of Sears.

The climatic changes which occurred in the Fox Prairie area during postglacial times apparently were: a cool, moist climate, supporting

Abies and Picea; a drier, warmer climate, during which Abies and Picea decrease, while Pinus, Larix and broadleaf genera make their appearance; a cooler, moist climate, during which Abies and Picea again become conspicuous and the broad-leaved forest is definitely retarded; a dry, warm climate, which witnessed the disappearance of Abies and Picea and the increase of a forest type which was essentially oak-hickory; and lastly, a more moist, warm climate, supporting beech-maple. Such a succession of postglacial climates would tend to agree with the Blytt-Sernander hypothesis (17). This theory holds that there have been two periods of greater humidity in postglacial times. In Europe, where this theory was advanced and a great deal of investigation of postglacial climate has been carried on, workers in general agree with this hypothesis.

Paleobotanists have emphasized the need for a more extensive and exhaustive investigation of peat deposits in North America. Until these have been made, any interpretations or reconstructions of postglacial migration and climate are provisional. It is with this in mind that the writer submits his investigations in hope that they may, in a small way, be a contribution to a more comprehensive knowledge of post-Pleistocene climate and vegetation.

SUMMARY

1. The pollen analysis of the Fox Prairie bog reveals that the upper 2 feet of peat were deposited during a period unfavorable to the preservation of pollen grains.
2. Abies and Picea were the dominant genera in the lower levels.
3. The transitional period from coniferous to broad-leaved forest was gradual and was characterized by *Pinus* and *Larix maxima* and the general increase of broad-leaved genera.
4. The broad-leaved forest following the transition period was essentially oak-hickory.
5. The uppermost levels (15- to 13-foot) in which pollen was found, point towards the decrease in *Quercus*, the appearance of *Acer*, and to the present day beech-maple climax.
6. The successive forest types indicate the following fluctuations in climate: cool moist, warm dry, cool moist, warm dry, and warm moist.
7. This succession of climates agrees with the Blytt-Sernander hypothesis.

The writer wishes to express his gratitude to Dr. J. E. Potzger for helpful advice in directing this work, references to literature and critical reading of the manuscript; to Dr. R. C. Friesner for his helpful suggestions and generous assistance; to Paul B. Sears, of the University of Oklahoma, for checking the identification of several pollen grains; and to the members of the Butler University Botanical Department for their aid in boring the bog and their kindly cooperation and interest.

LITERATURE CITED

1. ARTIST, R. C. Stratigraphy and preliminary pollen analysis of a Lake county, Illinois, bog. *Butler Univ. Bot. Stud.* 3:191-198. 1936.
2. CLELAND, H. F. Geology: Physical and historical. American Book Co. 1925.
3. DAVIS, C. A. Origin and distribution of peat in Michigan. *Rept. Mich. State Bd. Geol. Survey.* 1907.
4. GEISLER, F. A new method for separation of fossil pollen. *Butler Univ. Bot. Stud.* 3:141-145. 1935.
5. HOODEK, P. K. Pollen statistics for two Indiana bogs. *Indiana Acad. Sci. Proc.* 42:73-77. 1932.
6. HURST, L. A., *et al.* Soil survey of Hamilton county, Indiana. U. S. Dept. Agri. Bureau of Soil Surv. 1914.
7. LEWIS, I. F., and E. C. COCKE. Pollen analysis of Dismal Swamp peat. *Jour. Elisha Mitchell Sci. Soc.* 45:37-58. 1929.
8. MALOTT, C. A. Handbook of Indiana geology. Part II. 66-256. 1922.
9. LINDSEY, A. J. Preliminary fossil pollen analysis of Merrillville White Pine bog. *Butler Univ. Bot. Stud.* 2:179-182. 1932.
10. SEARS, P. B. Pollen analysis of Mud lake in Ohio. *Ecology* 12:650-655. 1931.
11. —— Postglacial climate in eastern North America. *Ecology* 13:1-6. 1932.
12. —— Common fossil pollen of the Erie basin. *Bot. Gaz.* 89:95-106. 1930.
13. TRANSEAU, E. N. The Prairie Peninsula. *Ecology* 16:423-437. 1935.
14. VOSS, J. Postglacial migration. *Bot. Gaz.* 96:3-43. 1934.
15. WEAVER, J. E., and F. E. CLEMENTS. Plant ecology. McGraw-Hill. 1929.
16. WODEHOUSE, R. P. Pollen grains. McGraw-Hill. 1935.
17. WOODHEAD, T. W. The forests of Europe and their development in postglacial times. *Empire Forestry Jour.* 7:2-18. 1928.

POLLEN SPECTRUM OF LAKE CICOTT BOG, CASS COUNTY, INDIANA¹

By WILLIAM M. SMITH

This study is one of a series of investigations on fossil pollen in peat, carried on at Butler University during the winter and spring of 1936-37. To date very little work of this nature has been done in the state, and the importance of such research can readily be seen when one realizes that Indiana is vegetatively in a critical area, where great vegetations have moved to the north or to the south as successions controlled by major climatic changes, leaving as telltale records relic colonies of boreal plants (Friesner and Potzger, 9), but especially the more detailed account of their presence in fossil pollen in peat. In the northernmost tier of counties, remnants of boreal forests are still in existence (Deam, 5).

Lake Cicott is one of the southernmost lakes in Indiana, marking the border between the Tipton Till Plain and the Lakes Area. It is located ten miles west of Logansport on the north side of Highway 24 in Jefferson Township, Cass county.

The lake is one mile long east and west and has an average north-south width of one-fourth of a mile. Its greatest depth is fifty feet. The lake is surrounded by sand and clay bluffs on all but the east side, so that in times of high water it drains into Crooked creek through an old lake bed lying between it and the creek. It is not fed regularly by any stream and has no outlet except at flood stage. At the present time the western half of the basin is filled with peat, and vegetatively is in the sedge-meadow stage, controlled by *Calamagrostis canadensis* with colonies of *Typha tifolia* in depressions, and willows appearing as pioneers on the bog. Gorby (12) states that much of the land of Cass county was wet and swampy in its primitive state, but the soil is excellent for agriculture when thoroughly drained. The loamy, alluvial soil of the river bottoms produces immense crops in favorable years.

METHODS

Two sets of borings were made and these will hereafter be referred to as Spectrum A and Spectrum B. Spectrum A is located in the center of a large bog area about 350 yards west of the present lake. It records

¹This paper is a portion of a thesis in partial fulfillment of the requirements for the degree of Master of Arts in Butler University.

a depth of 31 feet. Extremely diluted peat was found at the 14- to 18-foot levels, and no samples could be obtained of these levels in Spectrum A. Spectrum B was taken between two high slopes on the north and south sides of the bog about 500 feet east of Spectrum A. Spectrum B was 29 feet deep, with such dilute peat at the 12-, 15-, 16- and 18-foot levels that no samples were obtained from these levels. In both cases the peat above and below the dilute-peat horizon consisted of a finely divided material.

The method used in mounting the peat for microscopic examination was that described by Geisler (10). A scalpelful of peat was placed into a small beaker together with 6 cc. of 95 per cent alcohol and three drops of gentian violet stain. The peat was then stirred very gently with a camel's hair brush until all the particles had thoroughly separated; in most cases this took about five minutes. Then it was allowed to settle. As a general rule, the beaker was placed on a tilt so that the soil particles could settle out in a concentrated mass. After the material had settled for about three minutes, a small amount of the surface layer of the sediment was collected in a pipette and three drops were placed on a clean slide. The alcohol was permitted to evaporate, and just before the material on the slide was dry, a drop of glycerine jelly was added and the two were mixed. A glass cover was then placed over the material and the slide was ready for examination. A preliminary examination was made of each mount to estimate the number of pollen grains present. This was done so that when the count and identifications were begun, it would not be necessary to make additional slides.

Gentian violet proved to be very satisfactory stain for pollen mounted in this manner. In the lower levels of marl, the grains did not take the stain so readily, and it is suggested that more stain be used, possibly four or five drops to 6 cc. of alcohol instead of three drops. However, near the surface of the bog it was found that two drops were sufficient. The variation in the amount of stain needed for good staining was probably due to the fact that the levels of marl were alkaline and did not take the stain readily, while the more acid peat near the surface took the stain very readily.

A binocular microscope equipped with a 15X ocular, a 4 mm. objective and a mechanical stage was used. Various opinions are held as to the number of pollen grains that should be counted in order to reduce sampling errors to a minimum. Godwin (11) states that counting 150 pollen grains from each sample is sufficient; Barkley (2) also supports this view.

In the present study, 200 pollen grains were counted for each horizon. In the lower levels, however, it does not seem necessary to count 200 grains, because only a few genera are represented and the percentage varies only slightly in 100- and 200-pollen-grain counts. Pollen of trees and shrubs only were considered. In the lower levels the pollen grains were not very numerous and it required as high as nine slides to count 200 grains, but as the depth decreased, the pollen grains increased in number, and from the 25- to the 18-foot levels, as a rule, one slide yielded 200 pollen grains. In some cases it was necessary to count only portion of one slide to obtain the required number. From the 18-foot level to the surface the number of pollen grains per slide decreased until near the surface four, and sometimes five or six, slides were necessary to obtain 200 pollen grains.

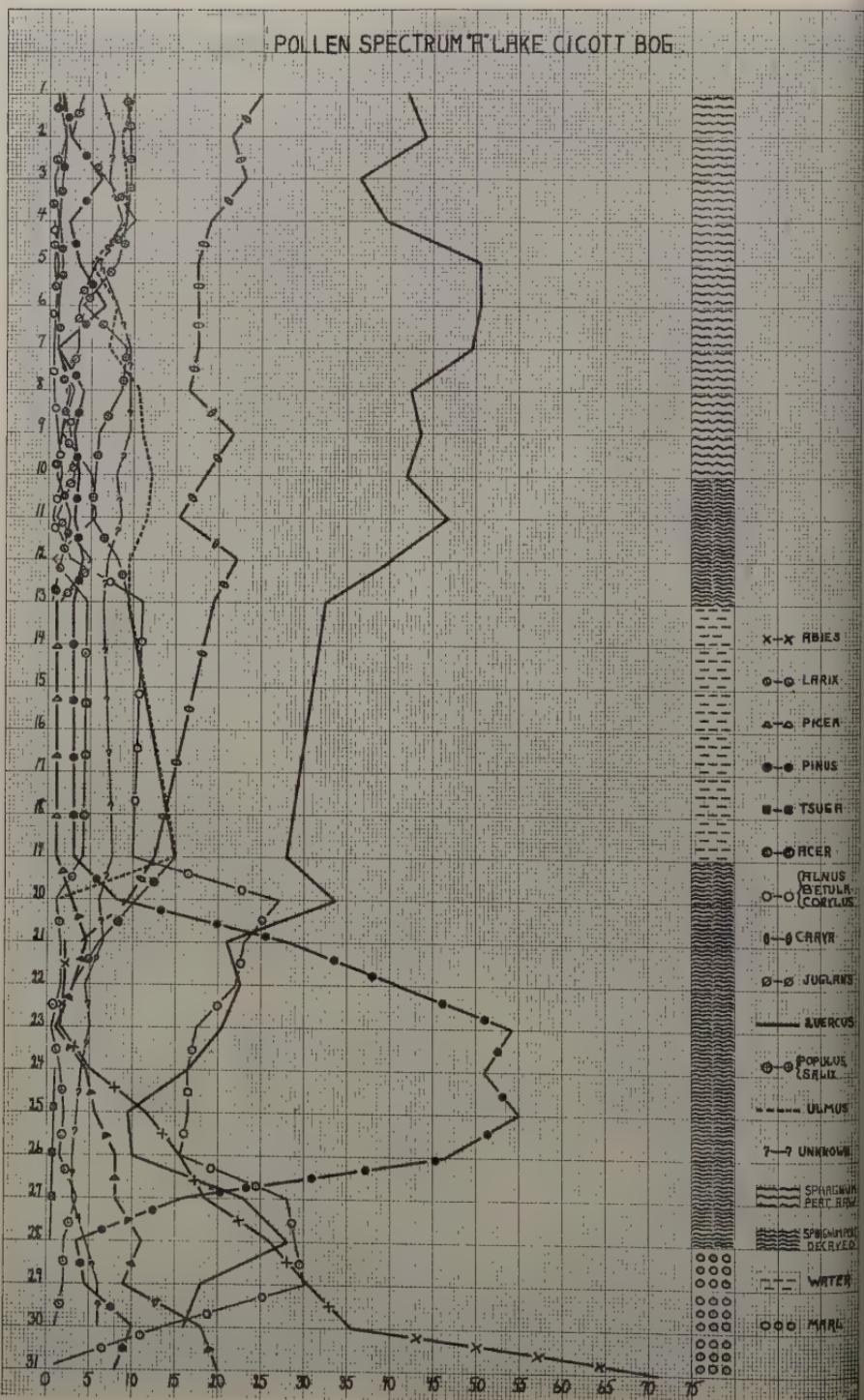
OBSERVATIONS

The peat of Spectra A and B was very similar in character, and so the description will refer to both borings. The peat was of a dark chocolate color and, near the surface where disintegration was not complete, sphagnum could be recognized as the major component of the organic remains. From the 10-foot level to the layers of marl at the bottom, the sphagnum had decomposed to such an extent that the peat was made up of fine particles, becoming more concentrated as the depth increased.

Between the 13- and 19-foot levels in A, and between the 11- and 13- and 19-foot levels of Spectrum B, no samples could be obtained. The peat above and below these levels was very dilute and loose, and the levels omitted very likely consisted of extremely watery peat, so little that the sleeve of the peat borer did not receive resistance enough from the surrounding material to permit it to open and collect a sample. At the 29-foot level in Spectrum A, marl appeared and continued to the bottom, increasing in density and sand content until at the 31-foot level consisted mostly of fine sand. In Spectrum B, marl appeared first in the 27-foot sample, and sand was reached at 29 feet.

Dachnowski (4) states that sphagnum peat is the most common and one of the most important peat deposits in the United States, also that sphagnum forms thick strata, whose plant composition is exceedingly rare and homogeneous. "The sphagnum peat is usually quite raw, but decayed strata are found on regular horizons in the layers of peat bogs, and there are often such instances when decayed sphagnum forms the entire layer of the peat bog with the exception of a few bottom layers." This is the exact condition at the Lake Cicott bog, in which the first ten

FIGURE 1



feet were raw sphagnum peat, and the horizon between here and the marl consisted of decayed sphagnum. A special study was also made of the acidity of the soil at the various levels. Readings were made with Youden hydrogen-ion concentration apparatus. Three readings were made from each level. Acidity was slight (pH 6.09), even in the top layer, and decreased with the increase in depth of the bog until at the lower levels the reaction was definitely alkaline.

The pollen grains are well preserved, and the peat separates readily and uniformly with the Geisler (10) method. Figure 1 shows pollen counts in Spectrum A. Figures for Spectrum B are not given in this paper, but will be supplied upon request by the Botany Department of Butler University. Outstanding is the definite dominance of conifers in the lower levels of the bog. *Picea* apparently did not assume so prominent a part in the early vegetation in this region as it did in many other localities in our country. At Lake Cicott it never exceeded 21 per cent in either of the two spectra, but *Abies* dominated in the forests represented by the lower levels. It was superceded by *Pinus* in the 26-foot level in Spectrum A, which apparently controlled the forest for many centuries.

All the symbols used for the different genera, except for *Carya*, *Acer*, *Larix* and unknowns, are the same as those used by Erdtmann (6). *Betula*, *Corylus* and *Almus* were grouped together under the symbol for *Betula*, and *Populus* and *Salix* were grouped under the symbol for *Salix*. These combinations were made to relieve the congestion of lines in the lower percentage columns, thus making the figure less difficult to read.

The records of the two spectra do not correlate very closely in the lower levels, neither as to species nor importance of one or the other. A possible explanation for this will follow later in the discussion. There is, however, a very close correlation in the two spectra in the *Quercus-Carya* climax from the 13-foot level to the surface. *Betula*, *Alnus* and *Corylus*, combined in Figure 1 to reduce complications, reach 30 per cent at the 9-foot level, gradually decrease to the 26-foot level, after which they increase gradually to the 20-foot level. A marked decrease was noticed from the 20-foot level upward until at the 4-foot level they disappeared completely.

Larix shows no prominence in Spectrum A, but has a creditable representation in several levels of Spectrum B, while *Thuja* is outstanding by its absence even at levels where one would expect it as an important constituent in the bog forest. It is a well-known fact that the pollen of both of these species is extremely fragile and does not preserve well, and this, no doubt, explains their absence here.

Populus and *Salix* make their first appearance at the 22-foot level (Spectrum A) and remain fairly constant to the surface of the bog. *Juglans* makes its appearance at the 19-foot level and shows a gradual increase in percentage to the 4-foot level, after which it is slightly irregular to the surface. *Ulmus* appeared first in the 20-foot level, showing a sudden increase in the next-foot level to 15 per cent of the total, and then ranging between 10.5 and 5 per cent to the surface of the bog.

DISCUSSION

The need for the study of fossil pollen in peat bogs in general is important in view of the fact that it is an outstanding method of tracing the history of the vegetation in temperate regions bordering on boreal forests. Such work is necessary in order to understand the present-day vegetation of certain localities, for example, the relic colonies in different parts of the state and discussed in papers by Friesner and Potzger (9).

All the bogs studied had marl at the bottom, ranging in depth from 2 feet to as high as 16 feet. At the Lake Cicott bog the depth of the marl was only 3 feet. Evermann and Clark (8), in making soundings in Lake Cicott, found an abundance of *Chara*, which was probably responsible for most of the marl deposits of the Lake Cicott bog during the stage of open water.

Various methods are used to separate the pollen grains from the peat. Sears (21) states that boiling the peat in a 10 per cent solution of potassium hydroxide and mounting in glycerine jelly is a satisfactory method. G. Erdtman and H. Erdtman (7) state that boiling in alkali is a rather severe treatment, but present a new method that seems even more severe, in which the peat is soaked in cold 10 per cent sodium hydroxide, pressed through a metal net (4 mm. mesh), acidified with dilute hydrochloric acid (1:1), filtered through a Buchner funnel, dried on a glass plate, ground in a mortar and sifted through a 4 mm. mesh net. Potzger (18) objects to the use of potassium hydroxide for the separation of peat because of the apparent error introduced by the distortion and possible destruction of some pollen grains. The Geisler (10) method eliminates all of the above objections, because it does not introduce errors by distortion and breakage and perhaps total destruction of pollen grains, especially of the more fragile kinds. We found very few broken conifer pollen and even the *Larix* was retained quite intact.

The results of the acidity study are striking, in that approximately only the first ten feet were slightly acid, changing to neutral and then to alkaline as the depth of the bog increased. Kurz (15) classifies bogs

under two general types, "acid bogs" and "circumneutral bogs," according to the prevailing reaction. He states that "one sees a definite correlation between high acidity and the presence of sphagnum." The Lake Cicott bog is one of the "circumneutral type," in so far as the pH readings are concerned. However, the raw peat near the surface is made up almost entirely of sphagnum. The possible explanation is that periodic fires have passed over the sedge meadow and have created an alkaline reaction on the surface of the bog, and the seepage of the ash into the bog thus decreased the acidity of the peat.

We now turn our attention to the succession of vegetation as indicated by the pollen record of the bog. *Abies* was the dominant genus at the lowest level in both spectra, and associated with it were *Picea*, *Pinus* and the *Betula-Alnus-Corylus* group. *Abies* decreased rapidly at first, then more gradually, and disappeared entirely above the 20-foot level. At no time was *Picea* represented as a dominant species, though both *Picea* and *Pinus* were more prominent in B than A. *Pinus* was represented at the bottom level, and held its own for the next four feet; then in Spectrum A a sudden increase made it the dominant species for the next seven levels, after which it showed a gradual decrease, but was still represented in the surface of the bog. In Spectrum B, however, *Pinus* suddenly decreased in the 24-foot level and never again became prominent. In Spectrum A, *Quercus* made its first appearance one foot from the bottom of the bog, increased for three layers, then decreased, reaching its lowest percentage at the same level that *Pinus* reached its highest percentage. *Pinus* and *Quercus* show the same struggle for dominance in both spectra. *Pinus* decreased to a very low percentage, but was represented in every level to the surface of the bog. *Pinus*, however, showed the greatest variation of any genus represented in the two spectra. In Spectrum B, *Pinus* was represented by 48 per cent at the 20-foot level, while in A the highest percentage (55) was recorded at the 25-foot level. This variation in the two spectra may be attributed to the fact that an open water stage may have developed in the bog mat, and the pollen grains did not settle as they did in the other regions of the bog; or oak trees may have dominated that particular area near the bog, and the wind currents were such that the *Quercus* pollen was scattered over the surface of the bog in that particular area in greater abundance than that of *Pinus*. After *Quercus* became dominant over *Pinus*, it continued to increase in its percentage and, with *Carya*, formed the climax to the surface of the bog. Oak-hickory was still the climax forest about the lake when civilized man appeared on the scene.

Voss (22) states that, "In all the Illinois bogs under discussion, *Abies* and *Picea* pollen reached their maximum at the bottom of the bog and decreased near the surface, the decrease in some cases being gradual while in others it is abrupt. *Quercus* pollen was found in all bottom peat, and its percentage gradually increased towards the surface, the percentage remaining rather constant during development of the major portion of the bog. *Pinus* was found at practically all levels, and its percentage was rather constant in all bogs from bottom to top." The above results agree very closely with those found at the Lake Cicott bog, with the exception of *Pinus*, which dominated at Lake Cicott from the 26-foot to 21-foot levels in Spectrum A and 27- to 25-foot levels in B. The pollen diagram showing the major species reported by Voss (22) on the Hastings bog is very similar to that of the Lake Cicott bog, with the exception of *Pinus*, which becomes dominant for a time at Lake Cicott bog and does not at the Hastings bog.

Reporting on his studies of 28 bogs, Auer (1) states, "In the bottom layers of the peat bogs of southeastern Canada, *Picea* and *Abies* pollen appear in abundance, but a little higher up their curves drop to a minimum, when the pollen of the hardwoods reach their highest value. In the surface parts the pollen amount of spruce trees again increases, whereas that of hardwood is decreasing." In Lake Cicott, the fact that *Abies*, *Picea* and *Pinus* were dominant at the lower levels, giving way to the hardwood genera later, agrees with Auer's findings, but the hardwoods remain dominant to the surface at the Lake Cicott bog, while *Picea* begins to reappear and hardwoods decrease near the surface of the bogs studied by Auer. Houdek's (14) report on *Pinus* and *Quercus* in the Center lake bog correlates closely with the representation of these genera in the Lake Cicott bog.

Carya made its first appearance at the 21-foot level in Spectrum A and at the 24-foot level in B. From there it increased gradually to the surface of the bog. *Carya* became codominant with *Quercus*, and together they formed the climax genera to the surface of the bog.

Tsuga was found in a total of five different levels in the two spectra combined, but was represented by small percentages. In the Lake Forest formation, *Tsuga* today occupies only restricted or island-like areas. It must be considered in the study of a particular bog that the genera represented in its spectrum must have been located comparatively close to the bog itself. *Tsuga* could have been abundant near the bog, and still not be represented to any great extent in the pollen spectrum. The fact that its pollen disintegrates readily and its peculiar disjunct distribution

n the Lake Forest area would make one anticipate a low representation
n most pollen spectra. *Larix* first appeared in the 30-foot level and was
found in every level from this point to the surface of the bog. However,
it did not play a prominent part in the pollen spectrum at any time.

Thuja was identified in the 20- and 21-foot levels in Spectrum A, but
in only a small percentage. It was not found in Spectrum B. Sears (21)
states that, "Thuja breaks down quickly when wet." This probably
accounts for the low *Thuja*-content of the bog, and may also account for
the small representation of *Larix* pollen, for both of these genera are
dominant of later-stage bog forests. Hessler (13) first visited the regions
near Lake Cicott in 1894, and reported *Thuja* and *Larix* bogs thirty-five
miles north of Lake Cicott. It is common knowledge that the bogs of
northern Indiana had both *Thuja* and *Larix* present until cultural
influences, such as drainage, have changed the environment to such an
extent that the bog vegetations are rapidly decreasing. Potzger (17),
reporting on the post-Pleistocene fossil records of peat in Henry county,
states, "The logs are to all appearances remains of *Thuja* and *Larix*,"
and that, "Indications are that they represent the remains of a former
cedar-tamarack bog in the valley."

Acer came in first at the 13-foot level in Spectrum A and at the 7-foot
level in B, continuing from these levels to the surface, but the percent-
ages were very low. *Fagus*, too, played only a minor part in the pollen
spectrum of the bog, appearing in only three levels, with a very low
percentage, and in order to minimize complexity it is excluded from the
graph. *Fagus* and *Acer* apparently never played a prominent part in
the forest of that section of Cass county, and so the low pollen represen-
tation in the peat presents a true picture of the actual status of these
two genera.

Powell (20) states that when the settlers entered Cass county they
found an abundance of hardwood trees, but does not mention maple.
Beech was reported by the early settlers of the county; Hessler (13)
reports that *Fagus* was present in Cass county, but scattered, and that
there were very few beech trees in the vicinity of Lake Cicott.

Indiana is still in a critical state of vegetative development; in the
most favored areas, beech and maple are the climax species, but, taking
the state as a whole, there are no doubt more oak-hickory forests than
there are beech-maple. Potzger (19), investigating the relation between
topography and forest types in Monroe county, finds that the forest
type of any region may vary decidedly within a very short distance,
where topographic changes are abrupt. He states: "The striking feature

of all these uplands is the dual climax aspect. The north-facing slopes are mixed hardwoods with a strong tendency to beech-maple, while the south-facing slopes are oak-hickory. The controlling factor in this distribution of forest types is probably an edaphic one, chief of which is evidently soil moisture, influenced by difference in insolation and depth of soil." Lake Cicott is deeply sunken, and the land surrounding the lake is elevated approximately 60 feet and consists of sand and clay ridges. These features, along with edaphic factors, are the possible reasons for the presence of oak and hickory and the absence of beech and maple in the immediate vicinity of the lake. Voss (22), investigating bogs of northern Illinois, reports practically the same conditions, with neither beech nor maple playing an important part in the pollen spectrum of the bogs studied. Houdek (14), reporting on two northern Indiana bogs, does not list *Acer* at all, but his records show *Fagus* in almost every foot-level of both bogs studied, 12 per cent being the highest representation at any one level, but ranging much lower in most levels: usually from 3 to 8 per cent.

While *Ulmus*, *Juglans* and *Populus* indicate moderating climate, they only represent a transitional complex of the deciduous forest, a gradual filling in of wet lowlands. When the lower levels of peat were being deposited at Lake Cicott, the climate was probably comparable to the present outposts of forests in Alaska, gradually moderating to the type of climate now present in Canada, and the period shown on the spectra by the dominance of *Pinus* probably indicates a climate similar to that of our lakes region today, with *Abies* and *Picea* limited to bogs. The short dominance of *Abies* apparently indicates a rapidly moderating climate until it had become comparable to our present climate, and the decreasing conifer representation indicates relic conditions.

Populus and *Salix* grouped together appeared first at the 22- and 24-foot levels respectively. The percentages of these genera in the two spectra were very similar. *Ulmus*, also, shows a marked similarity in both spectra, appearing first at the 24-foot level in B and the 20-foot level in A. *Juglans* appears first at the 22-foot level in B, three levels earlier than in Spectrum A, its percentage of representation ranging from 1 to 4.5 in the different levels, and appearing in each level from the depth of its first appearance to the surface.

In general, we might say that the majority of the broad-leaved species appear a few levels sooner in B than in A, which apparently supports the explanation that the deeper depression (Spectrum A) filled in earlier

and more uniformly, thus presenting a truer picture of the successional and climatic changes than Spectrum B.

In spite of variations, both spectra show an *Abies-Picea* climax in the lower levels, displacement by *Pinus*, an ultimate *Quercus-Carya* climax, with *Pinus* persisting as relic to the one-foot level.

SUMMARY

1. A Canadian type of coniferous forest is indicated in the lowest levels of Lake Cicott bog.
2. *Abies-Picea* dominance persisted for a period represented by the lowest three levels of the spectrum.
3. *Pinus-Betula-Quercus* of the 29-foot level is superceded by *Pinus*.
4. *Pinus* dominates the 26- to 22-foot levels, after which it gives way apidly to *Betula-Quercus*.
5. *Quercus* and *Quercus-Carya* dominate from the 19- to the 1-foot levels, and *Quercus-Carya* forest covered the region about Like Cicott when civilized man moved in.
6. The order of disappearance of conifers is *Abies*, *Picea*, *Pinus*, the latter persisting as relic to the 1-foot level, but was not present when settlers moved in.
7. The low representation of *Thuja*, *Larix* and *Tsuga* is attributed to instability of the pollen of these species.
8. Moderating climate is also indicated by such lowland species as *Ulmus* and *Juglans*.
9. The Lake Cicott bog indicates the following forest succession: *Abies-Picea*, *Pinus* and deciduous forests, of which *Quercus* and *Carya* formed the climax, with *Ulmus* and *Juglans* the subclimax.

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LITERATURE CITED

1. AUER, V. Some problems of peat investigations in Canada. Canadian Geol. Survey. Summary Report. Part C. 1927.
2. BARKLEY, F. A. The statistical theory of pollen analysis. Ecology 15:283-289. 1934.
3. BENEDICT, A. C., and M. M. ELROD. A partial list of the flora of Wabash and Cass counties, Indiana. Indiana Dept. Geol. and Nat. Res. 17th Report. 26-272. 1891.
4. DASHNOWSKI-STOKES, A. P., and V. AUER. American peat deposits. Handbuch der Moor Kunde Bd. 7. 1933.
5. DEAM, CHARLES C. Flora of Indiana: On the distribution of the ferns, fern allies and flowering plants. Indiana Acad. Sci. Proc. 23:39-53. 1923.
6. ERDTMAN, G. Boreal forests and the theory of pollen statistics. Jour. Ecol. 19:158-163. 1931.
7. ERDTMAN, G., and H. ERDTMAN. The importance of pollen analysis technique. Sv. Bot. Tids. 27:347-357. 1933.
8. EVERMANN, BARTON W., and H. W. CLARK. Lake Cicott, Indiana, and notes on its flora and fauna. Proc. Biol. Soc. Washington 21:213-218. 1908.
9. FRIESNER, RAY C., and J. E. POTZGER. Studies in forest ecology. Butler Univ. Bot. Stud. 2:135-150. 1932.
10. GEISLER, FLORENCE. A new method for separation of fossil pollen from peat. Butler Univ. Bot. Stud. 3:141-146. 1935.
11. GODWIN, H. Pollen analysis. An outline of the problems and potentialities of the method. Bot. School, Cambridge 33 (4). 1934.
12. GORBY, S. S. Indiana Dept. Geol. Nat. Res. 19th Annual Report. 1894.
13. HESSLER, ROBERT. Notes on the flora of Lakes Cicott and Maxinkuckee. Indiana Acad. Sci. Proc. 6:116-129. 1896.
14. HOODEK, PAUL K. Pollen statistics from two Indiana bogs. Indiana Acad. Sci. Proc. 42:73-77. 1932.
15. KURZ, HERMAN. Influence of Sphagnum and other mosses on bog reactions. Ecology 9:56-69. 1928.
16. NICHOLS, G. E. The hemlock-white pine-northern hardwood region of eastern North America. Ecology 16:403-422. 1935.
17. POTZGER, J. E. Post-Pleistocene fossil records in peat of the upper Blue river valley, Henry county, Indiana. Indiana Acad. Sci. Proc. 45:65-68. 1936.
18. —— Succession of forests as indicated by fossil pollen from a northern Michigan bog. Sci. 75:366. 1932.
19. —— Topography and forest types in a central Indiana region. Amer. Midland Nat. 16:212-229. 1935.
20. POWELL, JEHU Z. History of Cass county, Indiana. 1913.
21. SEARS, PAUL B. Common fossil pollen in the Erie basin. Bot. Gaz. 89:95-106. 1930.
22. VOSS, JOHN. Postglacial migration of forests in Illinois, Wisconsin and Minnesota. Bot. Gaz. 96:3-43. 1934.

POLLEN STUDY OF CRANBERRY POND NEAR EMPORIA, MADISON COUNTY, INDIANA¹

By JEAN BARNETT

This paper is one of a series of fossil pollen studies carried on in the Botany Department of Butler University. In this work peat was collected from a number of bogs distributed over the northern half of the state. One of these is Cranberry pond near Emporia, Madison county, Indiana. The modern flora of Indiana as a whole is that of a mesophytic deciduous forest. Interspersed within the present forest areas are to be found numerous relic colonies of former vegetational climaxes. These relic colonies are of two main types, viz., prairie relics of grassland species and boreal relics of northern species. In so far as the present study is concerned, only the tree members of the latter type of relic colony are of importance. These consist of such trees as hemlock, white pine, tamarack and *arbor vitæ*. It is well known that the modern range for these trees far north of Indiana, especially northern to the present-day colonies and in the state. The presence of these trees in Indiana so far south of their modern range indicates that at one time Indiana had a very different floral aspect. Perhaps these so-called relic species, along with other boreal plants, were once the dominant species, and the present-day climax associations which we now find so common were unknown in this region. Such is the hypothesis that is proposed on the strength of the results of this series of fossil pollen examinations.

In the present study, pollen analysis has been mainly concerned with tree pollen, not only because the trees form the dominant vegetation and cause of its abundance, but also because it gives the most direct indices of past climates and of postglacial vegetation (Godwin, 8).

BOGS AND THEIR FORMATION

According to Potzger (16), a bog is a definite life association or "biome," which results in the formation of a specific type of soil. In the writer's opinion, this seems to be a very accurate description. This specific soil formation may be above the surface, where mass accumulation results

¹This paper is a portion of a thesis in partial fulfillment of the requirements for the degree of Master of Arts in Butler University.

in a building up of vegetation as in the high moors of Europe, or below the surface in depression areas where drainage is poor. This last named is the common condition in North America.

The typical bog in Indiana is of "kettle hole" origin. These usually developed from the melting block of ice which had been buried in the drift as the ice retreated (Cleland, 3). When the block of ice melts, a small kettle lake is formed, sphagnum moss comes into the lake and the life cycle of a bog has begun. In glaciated regions, bogs of all stages can be found. Some lakes have merely boggy borders, where the accumulated vegetable deposits have begun the work of filling, others are nearly or quite filled; often only a small pool is left in the center showing where the last of the filling-in process is in progress. Cranberry pond is evidently a very old bog, as it is completely filled.

Most bogs have marl deposits in their lower levels. In the present series of investigations at Butler University, these marl deposits vary in depth from one to twelve feet. According to Smith (19), the deposition of marl is due to the action of several *Cyanophyceæ*.

Many writers hold that the acidity of the water and peat is a feature of a typical bog, but Potzger (16) has found that this is not necessarily true with all bogs. The reaction may be acid or alkaline. Cranberry pond gave an acid reaction, but a bog examined near Logansport, Indiana, gave a nearly neutral reaction.

Fossils of both plant and animal remains are found in these peat deposits. Potzger (17) reports the finding of a set of mastodon tusks and deer and elk antlers, as well as logs of *Thuja* and *Larix*, in the upper Blue river valley in Henry county, Indiana, an area only twelve miles east of the Emporia bog. So well preserved, also, is much of the vegetation present in bogs, that it has been possible to separate out the twigs and leaves of different plants and definitely identify them. In this way, plants that inhabited the bog many thousands of years ago have been discovered, and we find for the most part that the pollen grains are in perfect condition, almost exactly resembling those of our modern trees.

LOCATION, TOPOGRAPHY AND VEGETATIONAL FEATURES

Cranberry pond, the bog under consideration in this paper, is located in the southeast corner of Madison county, about a half-mile south of the little town of Emporia and just east of the Big Four railroad tracks. Madison county is located in the central part of Indiana, northeast of Indianapolis. This region is a part of the Tipton Till Plain, having been

raversed by both the Illinoian and Early Wisconsin ice sheets. It is a region covered by glacial till of nearly level surface, with few lakes and dissecting streams (Welch, 22). The surface of Madison county in general consists of a gently undulating plain, with broad, level, interstream areas, more or less rolling as they near the water courses (Avon Burke and Ruhlen, 2).

The bog occupies approximately fifteen acres and is surrounded by a relatively flat tableland of fertile soil. Just south and southeast of the bog is a woodlot of deciduous trees. The bog is at present covered chiefly with *Cypha* and *Calamagrostis*. Scattered clumps of *Osmunda regalis spectabilis* are still to be found and *Rhus vernix* is to be found on the east side. Formerly a considerable number of cranberry plants were present, according to Miss Rosa Markle, who has lived on the farm where the bog is located since 1870, but recent fires have completely destroyed them.

METHODS

Two borings were made in the bog by means of a peat borer of the cylinder type with a movable sleeve. The first hole was in the north-central portion and was made twenty-one feet in depth. The second boring was about fifty yards southwest of the first and reached a depth of thirty-two feet. The latter boring was approximately the center of the bog. Samples were taken at each foot-level from the surface to the bottom, which was indicated by the presence of sand and gravel. To avoid contamination, the borer was carefully washed at each descent and care was taken to be sure that each sample came from the center of the core and did not touch the sides of the chamber. The sample was immediately placed into a small glass bottle and stoppered. Contamination of the sample by pollen of the air was avoided, as the borings were made in October. Upon reaching the laboratory, the bottles were sealed with paraffin to prevent drying out.

By means of the Youden hydrogen-ion apparatus, the pH for each foot-level in both borings was taken. Two readings for each level were made and from the average active acidity the pH for the level was determined.

In the preparation of the peat samples for identification, the method of separation of fossil pollen from peat recommended by Geisler (6) was used with a few variations. This method was chosen over the alkali treatment used by Sears (18) and the treatment recommended by Erdtman and H. Erdtman (4) as it seemed to be more efficient and

less apt to introduce error by destruction of fragile pollen grains and distorting of conifer pollen by breakage of wings. Two hundred pollen grains were counted for each level and the percentage for each genus was computed. For accurate results Sears (18) says it is better to count not less than 100 grains, and Potzger (15) found no great percentage difference between 100 and 200 grain-counts.

Identification was based upon the descriptions and diagrams of Sears (18), descriptions and diagrams of Wodehouse (23), and upon slides made from pollen grains of modern trees. The conifers, *Abies*, *Picea* and *Pinus* were distinguished chiefly by size differences, and the rest by their pores, furrows and surface markings, as well as size differences. Slides for each level were finally examined to determine stratification of the bog and this was recorded in graph form in Figure 1.

HYDROGEN-ION REACTIONS

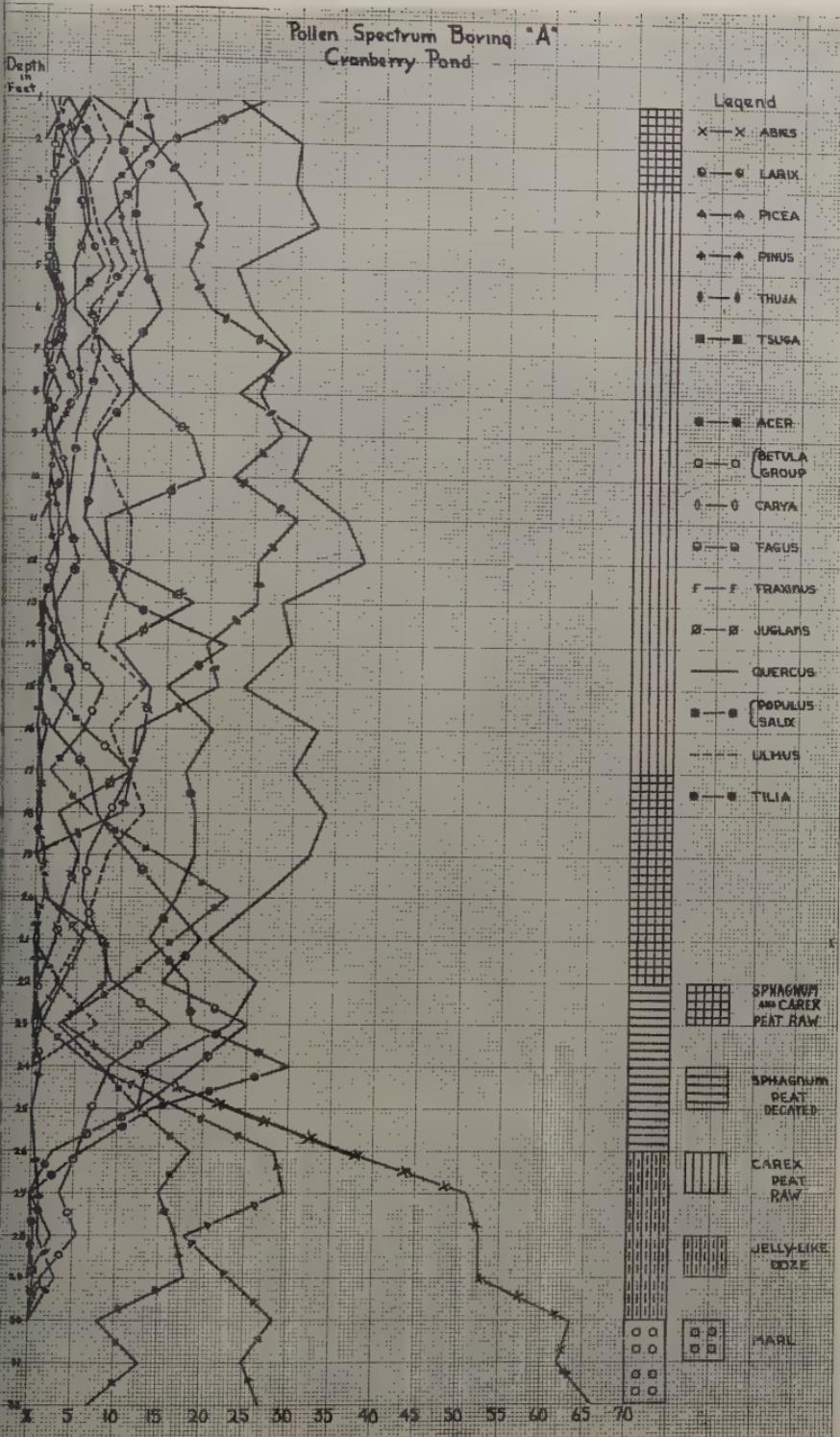
The acidity readings at comparable levels are remarkably close in the two borings. The first foot-level in each boring was barely above pH 6.0. In the second foot the reaction drops to pH 5.6 and 5.87 respectively. The reaction in Spectrum A begins rising in the third foot, while that in Spectrum B does not begin a definite rise until the fifth foot. The rise continues until the eight foot in Spectrum A and the twelfth foot in Spectrum B. From these levels the reactions vary little until the twenty-sixth foot in Spectrum A and the eighteenth foot in Spectrum B. At these levels a sudden rise to above pH 7.0 is found. Both spectra yield alkaline readings from these levels until the lowest levels are reached, Spectrum A ending at the 32-foot level with pH 7.97 and Spectrum B ending at the 21-foot level with pH 7.7.

POLLEN DETERMINATIONS

Two hundred pollen grains were determined in each foot-level for both borings. Percentages for each genus are given for Spectrum A in Figure 1. From these determinations we find that *Abies* and *Picea* dominate the lowest levels. These two genera, with a smaller percentage of *Pinus*, dominate until the 24-foot level, when the *Populus-Salix* group and *Larix* surpass them. Broad-leaved trees make their appearance in small numbers at the 29-foot level, with the *Betula* group in the majority.

Quercus and *Larix* control the spectrum at the 23-foot level; *Carya* comes into prominence at the 15-foot level, while near the surface *Carya* and *Quercus* control the spectrum.

FIGURE 1



Abies and *Picea* gradually lose out, the former disappearing at the 19-foot level and the latter at the 17-foot level. *Pinus* is the only genus found throughout the entire spectrum. It reaches a maximum of 22.5 per cent in the 20-foot level, decreases until near the surface, where it rises again to 12.5 per cent at the 2-foot level, and ends with 5.5 per cent at the top-level. *Larix* disappears at the 14-foot level and reappears only at the 8-foot level.

Acer and *Fagus* make their appearance at the 14-foot level. *Fagus* varies little from there to the top, but *Acer* gradually increases until it reaches 25.5 per cent at the 1-foot level. Here it forms a climax with *Quercus* at the expense of *Carya*. *Ulmus* and *Juglans* are prominent through most of this profile, forming a secondary climax.

A curve of the pollen percentages in Spectrum B would follow roughly that of Spectrum A. The conifers are found nearer the surface in Spectrum B. This may be correlated with the fact that Spectrum B is shallower than A. *Pinus* is found in every foot-level. *Quercus* and *Carya* control from the 14-foot level to the surface, but *Larix* and *Pinus* surpass *Carya* in several levels, with *Carpinus* also exceeding *Carya* in the 9-foot level. *Acer* and *Fagus* appear in the 14-foot level and, as in Spectrum A, *Fagus* remains about the same, while *Acer* gradually increases until it reaches 15.5 per cent at the 1-foot level. *Juglans* and *Ulmus* are prominent in a secondary way in this spectrum as in Spectrum A. Spectrum B differs from A in the absence of any definite dominants in the former. Grass, *Compositae* pollen and fern spores were not counted, but were observed in various levels.

The stratification in the bog is shown in Figure 1. Marl comprised the bottom two feet and a jelly-like ooze composed the next four feet. This was followed by decomposed Sphagnum-peat for the next four feet until the 21-foot level, where a combination of raw Sphagnum and *Carex*-peat was found. This persisted until the 16-foot level, where it gave way to raw *Carex*-peat, which continued until the 2-foot level, where raw Sphagnum and *Carex*-peat again combined.

DISCUSSION

Using as a basis the much-quoted statement of Auer (1), "The pollen content of the successive layers of the individual bogs is a direct indication of the comparative abundance of the different trees growing at the time the peat layers were forming," we can say that *Picea* and *Abies* controlled the forests in the vicinity of Emporia at the time the first

ayers of peat were being formed in Cranberry pond. Godwin (8) found that winged pollen grains travel greater distances than wind-carried pollen without such appendages. This might, of course, become a source of error in any pollen spectrum and will need to be kept in mind when interpreting horizons exhibiting both types of pollen. But the entire absence of nonwinged pollen below the 24-foot level can leave but one conclusion, viz., that the forests of the surrounding territory were essentially limited to winged-pollen conifers. We must, therefore, classify it as a typical boreal forest.

From the 24-foot level on, the broad-leaved trees, mainly *Quercus* and *Arya*, control the pollen percentages, replacing the conifers, which disappear rapidly, and finally, at the surface, *Acer* becomes dominant at the expense of *Carya*. This succession of trees, shown by the pollen diagram of Cranberry pond, agrees with the results of Auer (1), Sears (18), Potzger (15), Voss (20) and Houdek (10), all of whom have studied regions adjacent to Indiana. Voss (20) states that, "All pollen diagrams indicate that the conifers *Abies* and *Picea* were the first dominant trees to appear on the newly uncovered land. As the climate became warmer and edaphic conditions changed, the oaks, maples, etc., gradually invaded and gradually superseded the conifers on the uplands." This is the succession indicated in the Emporia bog.

If plants are indicators of climate, a cool, dry climate, indicated by *Picea* and *Abies*, was superseded by a warmer, more humid climate, indicated by the deciduous trees. The present-day succession of climaxes from Indiana northward is Beech-Maple in Indiana, *Pinus-Thuja* in the Lake Forest, and *Picea-Abies* in the boreal forest. The same order of succession occurs in this pollen spectrum from the bottom upward or, at time, from early postglacial period to the present. Reconstructing the vegetational picture of Indiana, Michigan and southeastern Canada: the conifers were forced far southward by the glaciers, crowding out or pushing the deciduous trees still farther south; then, as the ice melted and the glacier receded, the conifers followed in their wake, the deciduous trees advancing northward as climate and edaphic conditions became suitable. But here and there over the glaciated area were left patches

of conifers, relics of the former conifer climax. These relic colonies occupied spots which presented local conditions sufficiently rigorous, topographically, to permit them to compete, though in a gradually losing battle, for many centuries, with the invading broad-leaved species.riesner and Potzger (5) have shown that, in every case, areas occupied

by conifers in the relic colonies at Pine Hills and Trevlac have a more rigorous habitat than adjacent areas occupied by broad-leaved trees. In its ultimate effect, the microclimate in areas adjacent to these bogs remained comparable for many centuries to that of the boreal forest, and later to that of the Lake Forest of today.

The absence of *Thuja* pollen in this bog may be due to the fact that it does not preserve, but rapidly deteriorates in water (Sears 18). The presence of high percentages of *Larix* throughout the center of the bog is readily explained by the fact that it is an early invader of bog surfaces.

The presence of *Pinus* pollen throughout the pollen spectrum and its presence for many centuries after the disappearance of *Picea* and *Abies* is probably indicative of climatic changes from cold dry to warmer moister in so gradual a transition that *Pinus* could compete with broad-leaved species for many centuries before being finally eliminated in the last few centuries before our present time. *Pinus* evidently persisted as a relic until the rather recent past but was finally crowded out by the ever-widening control of the deciduous forest, favored, no doubt, by continued gradual climatic change which finally passed the limits of adaptability for pine.

The postglacial succession of forest vegetation as indicated by pollen analysis of this bog becomes: *Picea-Abies*, *Quercus-Larix-Pinus*, *Quercus-Carya* and *Quercus-Acer*, with *Pinus* occurring throughout the spectrum. The pollen percentages in the top level gives approximately the picture of the vegetation now occurring in the surrounding area.

Spectrum B agrees for the most part with Spectrum A in this order of succession but it does not show climaxes so well defined as in Spectrum A. It was taken nearer the edge, where, no doubt, the bog was filled in sooner. How much the encroaching fringe of shrubs and other marginal vegetation may have interfered with free deposition is unknown. It would appear, at least, that spectra taken from borings in the deepest part of the bog give the most clearly defined picture of vegetational history. A study of the comparative vegetational picture given by a succession of borings from edge to edge of a bog is at present under way in this laboratory.

The stratification of the bog shows that the bottom is sand, suggesting a former lake of glacial origin. The next two levels are marl, suggesting the presence of *Chara* or various *Cyanophyceæ* in an open water stage. This marl explains the alkalinity of the lower levels. The four feet of ooze on top of the marl suggests deposition under water. The next four feet are decomposed Sphagnum, indicating that Sphagnum was an early

habitant of the bog and suggesting deposition from the bottom of a floating mat. From the decayed Sphagnum to the surface is found raw Sphagnum and Carex, showing that deterioration was not complete and that Carex entered the bog later in its history. The absence of Sphagnum on the surface of the bog is correlated with the disappearance of such other boreal species as cranberry. These were destroyed by fire about fifteen years ago.

SUMMARY

1. Pollen analysis of peat and marl obtained from two borings in the cranberry pond bog near Emporia, Madison county, Indiana, show that Picea and Abies are dominant from 31-foot to 24-foot levels. These are replaced by deciduous genera, which dominate to the surface.
2. The order of succession has been: *Picea-Abies*, *Quercus-Larix-nus*, *Quercus-Carya* and *Quercus-Acer*.
3. *Pinus* occurs throughout the bog spectrum, persisting to within a few centuries of the present, but was not present when early settlers entered the territory.
4. Four main layers were found in the spectrum, viz., two feet of marl, four feet of ooze, four feet of finely disintegrated Sphagnum, with the upper 22 feet of raw Sphagnum and Carex mixed or raw Sphagnum.

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LITERATURE CITED

1. AUER, VAINO. Peat bogs in southeastern Canada. Canada Dept. Mines Memoir 162. 1930.
2. AVON BURKE, R. T., and LA MOTT RUHLEN. Soil survey of Madison county, Indiana. U. S. Dept. Agric. Bur. Soils. 1904.
3. CLELAND, H. F. Geology, physical and historical. 1925.
4. ERDTMAN, G., and H. ERDTMAN. The improvement of pollen analysis technique. Sv. Bot. Tidskr. 27:347-357. 1933.
5. FRIESNER, R. C., and J. E. POTZGER. Studies in forest ecology. I. Factors concerned in hemlock reproduction in Indiana. II. The ecological status of *Tsuga canadensis* in Indiana. Butler Univ. Bot. Stud. 2:133-149. 1932.
6. GEISLER, FLORENCE. A new method of separation of fossil pollen from peat. Butler Univ. Bot. Stud. 3:141-146. 1935.
7. GEYER, M. F. Animal micrology. 1917.
8. GODWIN, H. Pollen analysis. I. Technique and interpretation. New Phytol. 33:278-306. 1934.
9. GORDON, ROBERT B. A preliminary vegetation map of Indiana. Am. Midland Nat. 17:866-877. 1936.
10. HOODEK, PAUL K. Pollen statistics for two Indiana bogs. Indiana Acad. Sci. Proc. 43:3-7. 1932.
11. MALOTT, C. A. The physiography of Indiana. Handbook of Indiana geology. 21. 1922.
12. MARKLE, M. S. Phytoecology of peat bogs near Richmond, Indiana. Indiana Acad. Sci. Proc. 25:359-375. 1915.
13. PARKER, DOROTHY. Affinities of the flora of Indiana. Am. Midland Nat. 17:700-724. 1936.
14. PHINNEY, A. F. Henry county and portions of Randolph, Wayne and Delaware counties, Indiana. Indiana Dept. Geol. Nat. Hist. Ann. Rept. 15:97-116. 1886.
15. POTZGER, J. E. Succession of forests as indicated by fossil pollen from a northern Michigan bog. Science 75:366. 1932.
16. —— A notable case of bog formation. Am. Midland Nat. 15:567-580. 1934.
17. —— Post-Pleistocene fossil records in peat of the upper Blue river valley, Henry county, Indiana. Indiana Acad. Sci. Proc. 45:64-68. (1935) 1936.
18. SEARS, PAUL B. Common fossil pollen of the Erie basin. Bot. Gaz. 87:95-106. 1930.
19. SMITH, G. M. Freshwater algae of the United States. 1933.
20. VOSS, JOHN L. Postglacial migration of forests in Illinois, Wisconsin and Minnesota. Bot. Gaz. 96:3-46. 1934.
21. WEAVER, J. E., and F. C. CLEMENTS. Plant ecology. 1929.
22. WELCH, WINONA H. Boreal plant relics in Indiana. Indiana Acad. Sci. Proc. 45:75-88. (1935) 1936.